

Installation Aspects of the Third Harmonic Cavity and Super-Conducting Wiggler at ELETTRA

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Abstract

New cryogenic devices are going to be installed in the ELETTRA storage ring during the summer 2002. The Third Harmonic Cavity will improve the performance of the storage ring by increasing the beam lifetime while the Super-Conducting Wiggler has been designed for a new high energy-high flux diffraction beamline. Both of these devices are cryogenically cooled at 4K by liquid He circuits. In this contribution the main installation issues will be discussed (layout, vacuum chambers, cooled masks, cryogenic plants, etc.) and the adopted solutions will be presented.

Keywords: super-conducting wiggler, 3rd harmonic cavity, LHe cooling

1. Introduction

As a result of an enhanced development program for the facility, an increased number of beamlines have been recently installed at the ELETTRA Synchrotron Light Source. Nineteen beamlines are currently working, six of which are under commissioning, and three additional ones are under construction. In parallel to the beamlines' construction, a number of upgrades and new projects are being carried out on ELETTRA to improve the characteristics of the electron beam [1]. New insertion devices (ID's) are developed and put in together with their low-gap vacuum chambers, active feedback systems are installed to improve the stability of the accumulated beam and the overall operability of the machine, an upgrade program of the RF plants has been started with the purpose of providing the necessary operating margins to the RF systems and maintaining a good beam lifetime when all the foreseen Ids are operative and a full energy injector composed of a 100 MeV Linac pre-injector and 2.5 GeV booster Synchrotron will replace the present 1.2 GeV linac injector.

Of the eleven long straight sections available for ID installation (the twelfth is dedicated to injection), nine are presently equipped with ID's. In addition to the earlier five linearly polarized devices (undulators U5.6, U8.0, two U12.5 and the hybrid wiggler W14.0) and the Electromagnetic Elliptical Wiggler, three long straights are equipped with variable polarization undulators of the APPLE-II type for the Nanospectroscopy (two EU10.0), BACH (EU4.8 and EU7.7) and APE (EU6.0 and EU12.5) beamlines, respectively.

By the end of 2002, the two remaining long straights will be also equipped with Ids. A Figure-8 undulator is foreseen for the Inelastic Ultra-Violet Scattering (IUVS)

beamline and a Super-Conducting Wiggler (SCW) will provide photons to a second X-ray Diffraction beamline.

In order to compensate for the reduction in lifetime that will result from the action of the multi-bunch feedback systems, an idle super-conducting 3rd harmonic cavity (3HC) is being developed in collaboration with CEA-DAPNIA (Saclay, France) and the Swiss Light Source, Switzerland (SLS).

Both SCW and 3HC are cryogenically cooled at 4K by liquid He (Lhe) plants. Given the need of specifically designed storage ring vacuum chambers, the significant impact of these two devices on the overall facility and in view of a future integration of the associated cryogenic equipment, the SCW and 3HC will be installed close to each other along a single ID long straight.

2. The Super-Conducting Wiggler

The SCW has been designed and built by the Budker Institute for Nuclear Physics (BINP) in Novosibirsk (Russia).

The SCW consists of 49 dipole magnets with the following magnetic structure: $\frac{1}{4}$, $-\frac{3}{4}$, 1, -1, ..., 1, $-\frac{3}{4}$, $\frac{1}{4}$. The 45 full field central dipoles have a nominal field value of $B=3.5$ T ($B_{\max}=3.7$ T) and the magnet period length is 64 mm. The vertical field will produce a linearly polarized beam in the horizontal plane providing photons in the 10-25 keV range. The improvement in photon flux, with respect to the already installed 57-pole W14.0 –hybrid wiggler, spans from a factor of 3 at 12.5 keV to a factor of 14 at 25 keV.

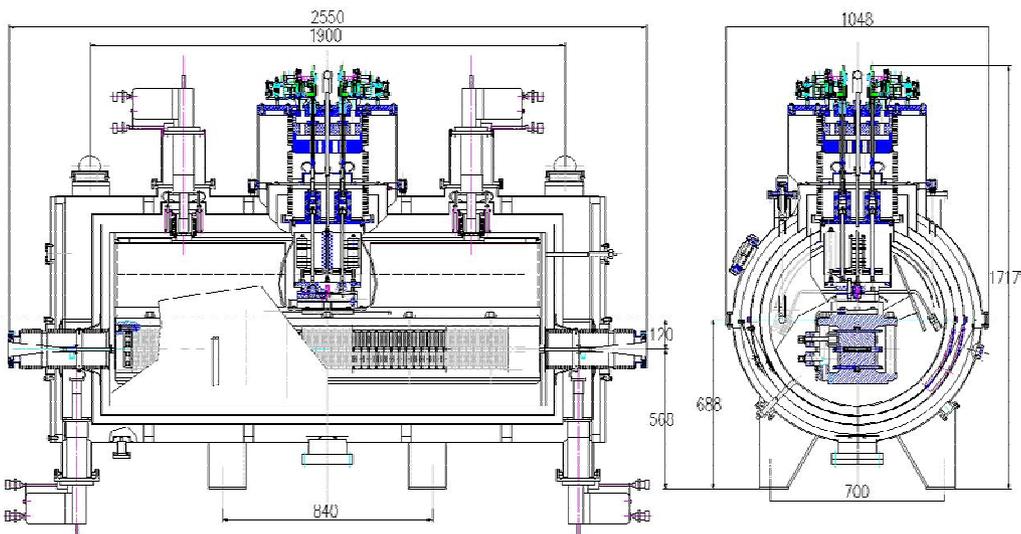


Fig. 1: Super-conducting wiggler.

The poles consist of iron yokes, which are used for closing the magnetic flux and as support for the superconducting coils. The yokes includes two parts that are placed

symmetrically above and below the median plane of the wiggler and clamped via spacers. The pole gap is 16.5 mm and the superconducting wires have a diameter of 0.915 mm and with insulation 0.925 mm; the number of filaments per wire is 8600 and the Cu/NbTi ratio is 1.4 [2].

The wiggler magnets are mounted in a special LHe cryostat that is placed in the internal part of the stainless steel vacuum vessel (Fig. 1). The cryostat is filled with LHe at 4.2 K and thermally isolated by two cold screens surrounding the cryostat itself. The inner screen is at 20 K, while the outer is at 60 K. The two screens protect the cryostat with respect to dissipation by radiation heat flux, whereas the convection heat flux is avoided by the insulating vacuum between the cryostat and the external vessel that must be better than 10^{-6} mbar.

The heat load parameters of the emitted total power (18.3 Kw) and power density (5.88 Kw/mrad^2) have a significant impact in the design of new components; in particular a new photon shutter has been designed for the Front-End [3].

3. The Third Harmonic Cavity

The 3rd Harmonic Cavity has been developed by CEA-DAPNIA Saclay for both the ELETTRA and the SLS storage rings. Since the two machines have similar requirements, a collaboration was started among the three institutes for the development of two twin cavities with only minor differences. The solution adopted is an idle sc system based on the SOLEIL two-cell cavity design, “scaled to 1.5 GHz” [4,5]. The collaboration agreement signed in October 1999 is now near to completion as both cavities have been constructed and tested. The SLS cavity has been installed and undergoing commissioning while the ELETTRA cavity will be installed in August 2002.

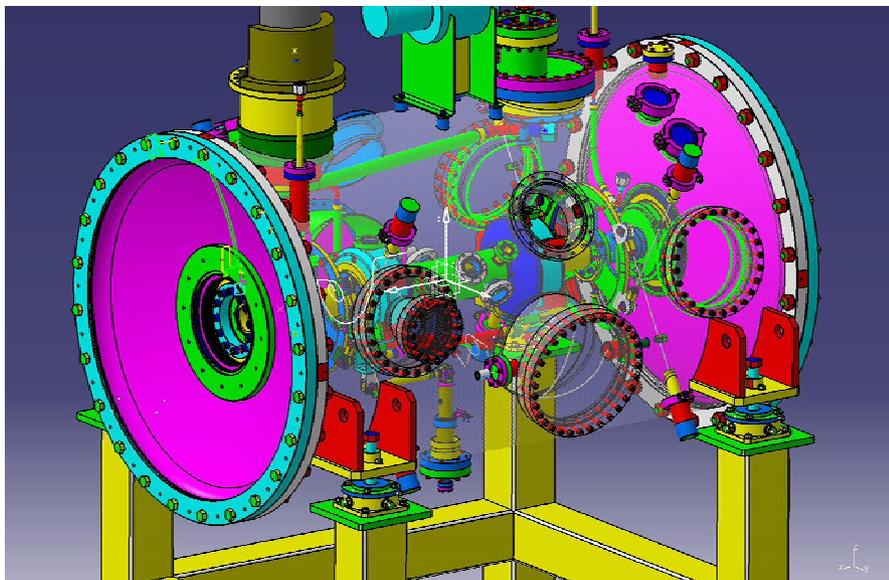


Fig. 2: 3HC cavity.

The purpose of the project is the improvement of the electron beam lifetime by a factor of 2 or 3, which can be obtained with a 3rd harmonic RF system through the lengthening of the bunches. This method is widely regarded [6] as the most efficient way of improving the beam lifetime without affecting the beam energy spread.

The 3HC cavity consists of two Cu/Nb cells (Fig. 2, in transparency) connected by a tube that allows the propagation of all modes except the fundamental one; this is obtained by a proper dimensioning of the tube diameter (94 mm).

The operating temperature is 4.5 K and each cell has a separate helium tank. The LHe is evaporated through the tanks and the gas is used to cool down the radiation shields of the internal cryogenic parts and of the cryogenic transfer line before being brought back to the refrigerator where it is liquefied and re-used in a closed circuit configuration.

The thermal convection losses are avoided by the insulating vacuum of the large external vessel (900mm diameter). The curvature of the large flanges is necessary to guarantee sufficient mechanical strength against external pressure. The curvature towards the inner direction results in a compact design with total axial length limited to about 1100mm.

4. Layout and New Vacuum Chambers

The main tasks of design office at ELETTRA were the management of the two projects with respect to the overall dimensions and interfaces, the development of the vacuum chambers with the integrated masks for the protection of the cryogenic parts from synchrotron radiation, the design of the necessary transitions between the different vacuum chamber section shapes, the design of the additional chambers that complete the straight section and, finally, the support system that allows for a friction free shrinking of the 3HC cryogenic elements.

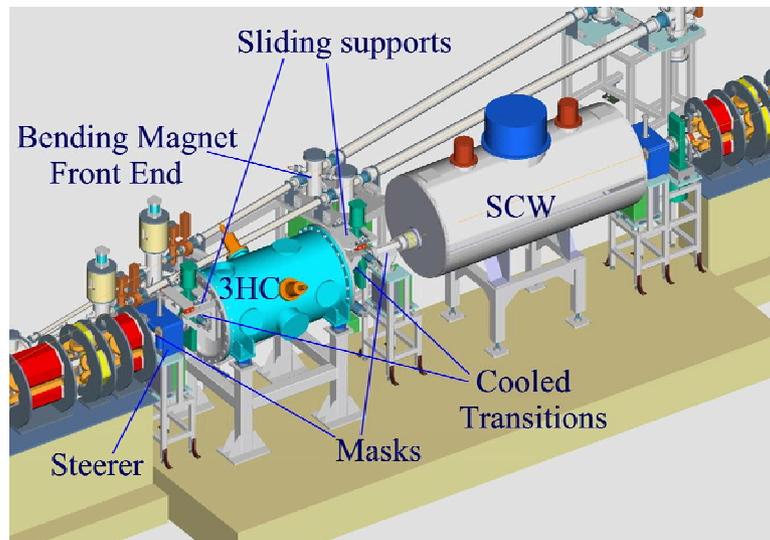


Fig. 3: 3D layout of section 11.

The development of a complete 3D layout of straight section 11 (Fig. 3), where the new devices will be installed, has proved to be an important task to check for interference and other possible incongruity with respect to the already installed devices. The most critical point has been shown to be the position of the 3HC cavity that is very close to the already installed Bending Magnet Front End. During the construction of the 3HC support system we have requested a modification to avoid an interference verified in the standard design, which was originally developed for the SLS cavity. Other important checks made possible by the 3D layout are the positions of the cryogenic ports, the layout of the associated piping and the study of the position of pre-vacuum and vacuum pumps and of instrumentation.

The synchrotron radiation masks have been designed starting from the standard vacuum chamber in two locations of the steerer magnets, to which a brazed copper element (Fig. 4-a) has been added on the side struck by synchrotron radiation. The cooling scheme is simple as the heat load to mask is quite low (about 100 W max.). The boundary conditions in the definition of the masks were the “smoothness” of the transition (maximum allowed angle between the incident plane and the beam direction is 12.5°), the minimum distance of the “tooth” from the beam axis and, finally, the maximum offset allowed in beam position with respect to the beam axis for which the masks could still be effective. This offset has been fixed to 2.5 mm, while the minimum distance of the “tooth” has been experimentally evaluated with some scraper measurements and fixed to 15.0 mm. Given these constrains it was impossible to shadow both SCW and 3HC with a single mask and it was necessary to design and install one mask for each device (Fig. 3).

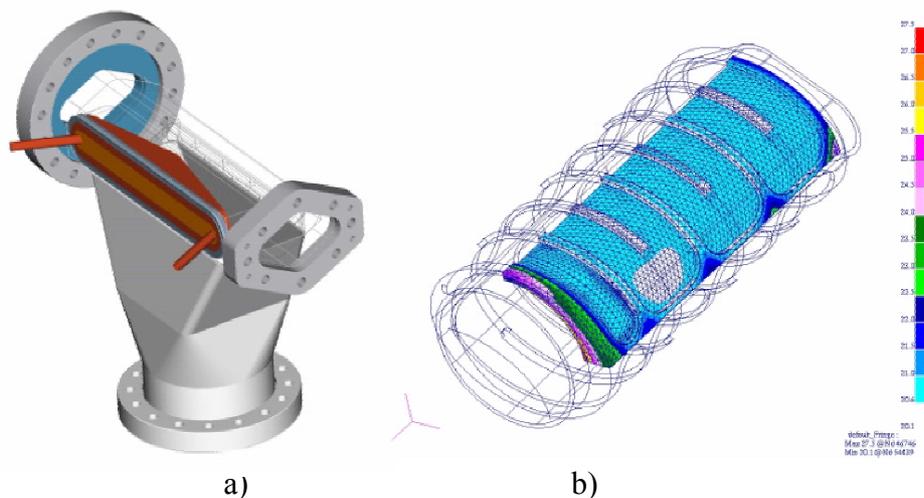


Fig. 4: Synchrotron radiation mask (a), cooled transition (b).

The cross section of the internal chamber for both the 3HC and SCW is different from the standard ELETTRA storage ring rhomboidal one. Smooth transitions have been used to minimize the contribution to the overall machine impedance. The transitions of SCW have been directly integrated in the device by the Russian manufacturer, starting

from an ELETTRA design. In the case of 3HC a number of external vacuum chamber pieces have been designed and manufactured by ELETTRA and sent to CEA-DAPNIA for final assembly. The external elements were the two transitions, the vacuum chamber with the pumping port, the chamber for pre-vacuum and instrumentation, together with a number of commercially available components, i.e. gate and angular valves, vacuum gauges and a ionic pump. As the transitions have to “trap” the high order modes coming out from the cavity a cooling system was necessary on the external casing of the chamber. The maximum calculated total power is 300 W, distributed on the internal surface of the transition. The material chosen is AISI 316 L for its low electrical conductivity that avoids the propagation of the modes. Fig.4-b shows the finite element thermal calculation for the transition. Assuming a water temperature of 20°C, the maximum temperature of the inside wall is kept under 30°C (27.5°C max.); this is obtained through a water cooling circuit that covers a wide part of the external surface, a high value for the water speed (6 m/s) and a low thickness of the wall (2 mm for the thinner parts). The requirement for an effective cooling is given by the need of avoiding additional thermal losses from the cryogenic parts.

All of the external chambers have been mounted at CERN, where a large clean room is available; particular care was taken against dust contamination because the cavity is very sensitive to this kind of pollutant and all the elements were mounted in a class 100 clean room. In order to prevent dust pollution, also venting and pumping during pre-vacuum has to be done very slowly. The final delivery of 3HC is done in static vacuum conditions, with all external chambers mounted.

Figure 5 shows the support system designed and manufactured at ELETTRA for the external chambers. The two gate valves and the connected chambers are hung on top of a sliding support that is free to move on the horizontal plane determined by the three SKF spheres, screwed on the fixed support. In this way the valves, connected to the other side of the bellows, are free to follow the shrinking of the cavity when it is cooled down to cryogenic temperature.

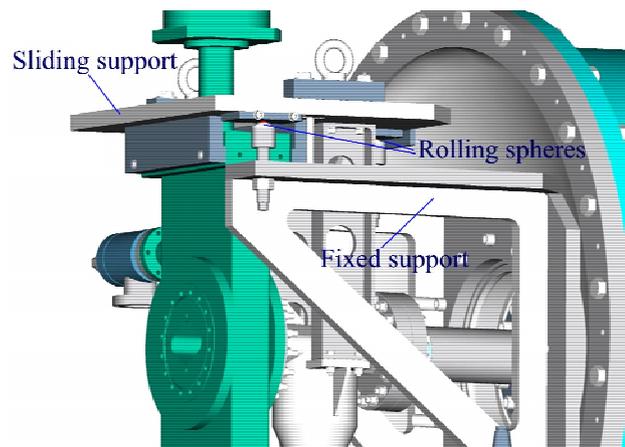


Fig. 5: Support system for the 3HC external chambers and valves.

exit temperature of the He gas is 300 K. Whereas the first three circuits bring He back to the refrigerator, the 300 K He is brought back to the compressor to be re-used. A valve box placed just outside the tunnel wall distributes the He fluxes through the different circuits.

All parts dealing with “warm” Helium (compressor, He tank, oil removal system, pipelines, valves, etc.) have been constructed under ELETTRA supervision, while the “cold parts” have been developed by Air Liquid.

The SCW and the 3HC devices include several safety and protection systems. Particular care is taken against possible quench events (rupture diaphragms, proper electrical protections, etc). Major safety measures have been taken for the Lhe circuits. The dewars, the Air Liquid refrigerator, the Leybold compressors, the valve box and the cryogenic lines have been grouped in the same restricted area, just outside the storage ring tunnel. The floor of this area has been covered with a stainless steel sheet, resistant against Lhe losses and protecting the below-floor installations (cables, pipes, etc.). A stainless steel hood has been installed over this area to extract large quantities of He gas that could be produced in case of Lhe losses. In order to avoid the saturation of He gas in case of accident, sensors have been installed that activate an extraction fan when a given concentration threshold is reached.

6. Conclusions

The design of mechanical components related to the installation of the cryogenic devices in section 11 did not imply significant conceptual problems. The main difficulties came from the management and integration of the different projects, which were developed by different institutes and companies “around the world”. The possibility of exchanging files through the network (documents and drawings), during the project development, has proved to be a powerful tool. For what concern drawings, the only “common format” found between the different technical offices is the autocad *.dwg, while the 3D models could rarely be interchanged and were usually rebuilt.

7. References

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